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CO-FLOW PLANAR SOFC FUEL CELL STACK

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BACKGROUND OF THE INVENTION

The present invention relates to fuel cells, particularly to solid oxide fuel cell (SOFC) stacks, and more particularly to a co-flow or counter flow planar fuel cell stack with an integral, internal manifold and a cell casing holder to separately seal the cell, thus providing improved sealing and gas flow as well as easy manifolding of cell stacks.

Solid oxide fuel cells are one of the most promising technologies for power generation. Like all fuel cells, SOFC cells are composed of two electrodes (anode and cathode) and an electrolyte. Since each single cell has a maximum voltage of about IV only, several cells must be stacked together in a stack to yield high voltages for practical applications. The stacking of the cells needs to address the gas flow distribution in the stack as well. The SOFC design closest to commercialization is the tubular design which can be assembled into larger units without the need of a seal. This sealess design is its biggest engineering advantage. However, the tubular geometry of these fuel cells limits the specific power density to low values because the electrical conduction paths are long,

leading to high energy losses from internal resistance heating. For these reasons, other fuel cell constructions are being actively pursed at the present time.

The most common alternative design is a planar arrangement with a cross-flow or radial flow arrangement. These planar fuel cells are constructed from alternating flat single cells, which are trilayer cathode electrolyte anode structures, and bipolar plates, which conduct current from cell-to-cell and provide channels for gas flow. Each individual cell, and the bipolar plate associated with every cell in the stack must be sealed together so that they are gas-tight at each manifold face. In addition the manifolds must be sealed gas-tight to the stack to prevent fuel and oxidant gas cross-leakage. The cross-leakage can compromise cell efficiency and is hazardous due to the possibility of explosion. Sealant materials which have thermal expansion coefficent matching with other components of the stack and with satisfactory durability at operating temperatures are not available at the present time. This presents a serious technological shortcoming for planar solid oxide fuel cells.

Planar fuel cell stacks may also be constructed using a co-flow or counter-flow configuration with internal manifolds, as exemplified by U.S. Patents No. 4,761,349 issued August 2, 1988; No. 5,227,256 issued July 13, 1993; No. 5,480,738 issued January 2, 1996; and No. 5,549,983 issued August 27, 1996. However, most of these designs were mainly developed for electrolyte-supported cells (thick electrolyte with thin electrodes). Since the electrolyte membranes are impervious, the sealing and the stack design are not as complex as for electrode-supported cells (one thick electrode serving as support and a thin film electrolyte). However, the electrode-supported cells have significantly higher performance than the electrolyte-supported cells because of lower resistance of the thin film electrolyte.

In some of the proposed designs such as the conventional cross-flow configuration, the sealing must be done at the edge and corner, which result in higher risk of leakage due to small seal area and less durable stack. Most of the stack designs proposed for electrolyte-supported cells are not applicable to electrode-supported cells because of the leakage through the porous electrode support.

The present invention provides a solution to the above-mentioned problems of planar fuel cell stacks, by providing a planar stack design with separate cell holders for improved sealing and reduced thermal stress problems. This design is particularly suitable for electrode-supported fuel cells because it promote face seal instead of corner seal; however, the design is applicable to electrolyte-supported cells as well. A key feature of the present invention is the cell holder that is separate from the interconnect itself.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved fuel cell stack.

A further object of the invention to provide a co-flow planar solid oxide fuel cell stack.

Another object of the invention is to provide a method of constructing a fuel cell stack which can also be used in electrolysis, gas separation, and other electrochemical systems requiring gas-proof separation of gases.

Another object of the invention is to provide a co-flow planar stack with integral, internal manifolding and a casing/holder to separately seal a cell using coventional sealing materials such as ceramic, glass, or glass-ceraminic based sealants.

Another object of the invention is to provide a co-flow planar stack which improves sealing and gas flow, and provides for easy manifolding of cell stacks.

Another object of the invention is to provide a co-flow stack and cell casing/holder which provides improved durability and operation with an additional increase in cell efficiency.

Other objects and advantages of the present invention will become apparent from the following description and accompanying drawings. Basically the invention provides a co-flow planar stack arrangement which can be utilized for solid oxide fuel cells and other electrochemical systems requiring separation of incompatible gases, such as used in electrolysis, gas separation, gas sensors, etc. The present invention overcomes the cross-leakage and other problems associated with prior planar fuel cell stacks designs, by providing a co-flow planar stack with integral, internal manifolding and a cell casing/holder to separately seal each cell using sealants such as materials based on ceramic, glass, or glass-ceramic. Such construction improves sealing and gas flow, and enables easy manifolding of cell stacks. The present invention utilizes a casing/holder containing a cell located intermediate a pair of flow channel/interconnects, with each cell having two pairs of openings at opposite ends which provide the separated co-flow of the fuel and oxidant gases.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated into and form a part of the disclosure, illustrate an embodiment of the invention and, together with the description, serve to explain the principles of the invention.

Figure 1 illustrates a multi-cell stack incorporating a two cell casing/holder and co-flow manifolding of the present invention.

Figure 2 illustrates an exploded enlarged view of component similar to those of Figure 1 for providing a single unit of a multi-cell stack.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides a unique construction for solid oxide fuel cells (SOFC) stacks. This construction improves sealing and manifolding problems of the cross-flow, counter flow, and radial-flow panar construction and, at the same time provides for co-flow of fuel and oxidant gases. A multi-cell (two cell) embodiment is shown in Figure 1, with Figure 2 illustrating enlarged exploded view of the components forming a single unit of the multi-cell of Figure 1.

As seen in Figure 2 a single cell unit includes a single cell located in a casing/holder plate is sandwiched between an anode plate and a cathode plate, indentified as flow channel/interconnect in Figure 2. Gas flow is provided to the cell with internal, longitudinal manifolds that are an integral part of the casing/holder plate and the electrode plates, the flow being shown in Figure 1. Each of the cell casing/holder plate and the electrode plates (flow channel/interconnects) includes two inlets and two outlets for gases. The peripheral surface of the cells are sealed to the surface of the casing/holder plate. only This surface sealing of the cell increases effective seal area and improves durability of the seal, as compared to conventional planar designs typically fabricated by edge and/or corner sealing. The Figure 1 embodiments illustrate a multi-cell assembly utilizing components similar to those of Figure 2, and shows the co-flow of both air (oxidant) and fuel through the entire stack using manifolds and flow channels in the cathode and anode plates. Note that, as

shown in Figure 1, the outer or end plates include only one pair of gas inlets/outlets, while the inner plates include a pair at each end.

Referring now to the drawings, the multi-cell of Figure 1, indicated generally at 10, comprises a lower end or outer electrode plate or flow channel/interconnect plate 11, a casing/holder plate 12 retaining therein a cell 13, an intermediate plate or flow channels/interconnect plate 14, a casing/holder plate 15 retaining therein a cell 16, and an upper end or outer plate or flow channel/interconnect plate 17. End plates 11 and 17 are provided with a pair of gas inlets or openings 18-19 and a pair of gas outlets or openings 20-21, respectively, and to which are mounted connects 22-23 and 24-25. The casing/holder plates 12 and 15 are each provided with two pairs of openings 26-27 and 28-29 at opposite ends, and intermediate flow channel/interconnect plate 14 is provided with two pairs of openings 30-31 and 32-33 at opposite ends. The plates 11, 12, 14, 15, 17 when assembled are positioned such that gas inlets or openings 18-19 plate 11 are aligned with openings 26-27 of plates 12 and 15 and openings 30-31 of plate 14, while gas outlets or openings 20-21 of plate 17 are aligned with openings 28-29 of plates 12 and 15, and openings 32-33 of plate 14. Plates 11 and 12 are constructed such that gaseous fuel 34 enters connect 22 in plate 11 and passes through opening 18 in plate 11 and opening 26 in plate 12 where after the fuel flow is divided and passes over cell 13 and through openings 30 in plate 14 and opening 26 in plate 15 and passes over cell 16, as indicated by arrows. The fuel passing over cell 13 passes through opening 33 in plate 14, opening 29 in plate 15 and opening or outlet 21 and connect 25 in plate 17, as shown by arrows and fuel exhaust arrow 35. Fuel passing across cell 16 also enters outlet 21 and connect 25 in plate 17. Air (oxidant) 36 enters connect 23 and inlet 19 in plate 11 and the flow is divided to pass over plate 11 and into opening

27 of plate 12 through opening 31 of plate 14 and across the plate 14 as indicated by arrows. The air passing across plate 11 enters opening 28 in plate 12, opening 33 in plate 14 and joins the air passing across plate 14 and then passes through opening 28 in plate 15, opening 20 and connect 24 in plate 17 as indicated by arrows and is discharged from connect 24 as indicated by air exhaust arrow 37. Top plate 17 and bottom plate 11 has flow channels on one side only, with a flat surface on the outer side as seen in Figure 1.

The construction of the flow channel/interconnect plates and the cells casing/holder plate is shown in greater detail in Figure 2. As shown, lower flow channel/interconnect plate 40 is provided with pairs of openings 41-42 and 43-44 and a plurality of spaced protruding members 45 forming flow channels or passageways 46 there between through which air passes at indicated plates 11 and 14 in Figure 1. Members 45 and flow channels 46 are located on both sides of any center plate, such as plate 14 in Figure 1, but are located on only one side of plates 40 and 60 in Figure 2. Cell casing/holder plate 50, similar to plates 12 and 15 of Figure 1, includes a pair of openings 51-52 and 53-54 at each end, central opening 55 and a cut-away or counter-sink 56 which defines a rim surface or flange 57 on which a cell 58 is mounted in a peripheral surface sealing arrangement. Cutaway 56 is also provided with two sets of angled slots 59 at each end and extending radically from openings 51 and 54 and provide gas flow distribution. Note that the cutaway 56 is configured to include opening 51 at one end and opposite opening 54 at the other end, which allows only passage of fuel across the cell 58 as seen in plates 12 and 15 in Figure 1. Flow channel/interconnect plate 60 is constructed similar to plate 40 and includes pavis of openings 61-62 and 63-64 at opposite ends and a pluriality of spaced members 65 forming passageways 66 there between. As shown, when cell 58 is

mounted in plate 50 and plates 40, 50 and 60 are assembled, the openings in the plates are in alignment for passage there through of air or fuel, as in Figure 1.

Should it be desired to form a single cell, the plates 40 and 60 of Figure 2 would be modified to omit or plug the openings 43-44 in plate 40 and the openings 61-62 in plate 60.

The arrangement of Figure 1 allows interchange of flows as follows: 1) opening 34; Fuel, 2) opening 36; Air, 3) opening 35; Fuel, and 4) opening 37; Air. Also, these opening can be interchanges to Air (openings 34 & 35) and fuel (openings 36 and 37).

It has thus been shown that the present invention provides a unique stack arrangement which includes a co-flow planar stack with an integral, internal manifold and a cell casing/holder to separately seal the cell. This construction improves sealing and gas flow, and provides for easy manifolding of cell stacks. While the description of the invention has been primarilary directed to a solid oxide fuel cell stack, it can be also utilized in electrolyzers, gas separation systems, etc. which are used in energy production and energy use. The invention has particular application for advanced fuel cells for stationary and transportation power generation. The co-flow arrangement of the present invention may be effectively utilized for planar single cells as well as for planar multi-cell stacks.

While particular embodiments of the invention have been illustrated and described to exemplify and teach the principles of the invention, and such are not intended to be limiting. Modifications and changes may be come apparent to those skilled in the are, and it is intended that the invention be limited only b the scope of the appended claims.